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Research on the Decision-making Mechanism of Digital Transformation of Small and Medium-sized Logistics Enterprises in China based on Evolutionary Game

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Abstract: In order to promote the transformation and upgrading of the logistics industry, in response to the problems existing in digital transformation of small and medium -sized logistics companies in China, this article uses the evolution game theory and methods to build a strategic decision model for digital transformation of small and medium -sized logistics companies in the market mechanism and government -driven, respectively and stability analysis of strategic selection. The results show that: direct returns, synergy coefficients and digital product service preferences of consumers have a significant effect on promoting digital transformation of small and medium -sized logistics companies; driven by the government, reasonable transformation direct subsidies and tax preferential efforts are conducive to improving small and medium -sized logistics enterprises The willingness of digital transformation; the effect of multiple policy subsidies is obvious, and the effect of direct subsidies is better.

Keywords: Evolution Game; Small and Medium Logistics Enterprises; Digital Transformation.

1. Introduction

In 2022, the "Fourteenth Five -Year Plan" Modern Logistics Development Plan issued by the State Council of China clearly requires that through digital technologies such as cloud computing, Internet of Things, blockchain, big data, artificial intelligence, etc., to accelerate the digital transformation of the logistics industry. Promote the improvement of quality and efficiency and reduction in the logistics industry. According to China's fourth economic census data, there are nearly 600,000 transportation, warehousing and postal legal entities in China, of which more than 90 % of the legal entities are small and medium -sized enterprises. It can be seen that small and medium -sized logistics companies are the development of the development of China's logistics industry and an important foundation for building a modern logistics system. It is also an important support for attracting employment and improving people's livelihood. Therefore, China wants to promote the construction of the modern logistics system, realize the cost reduction and efficiency of the logistics industry, and promote the digital transformation and upgrading of small and medium -sized logistics companies to achieve the high -quality development of the logistics industry. However, according to data released by the China Logistics and Procurement Federation, in recent years, the digital speed of small and medium -sized logistics companies in China has been significantly accelerated, but it still faces digital gaps [1], and what are the influencing factors? This is a problem worth pondering. As the promoter of the industry and the policy of policies, the government plays an important role in promoting the industrial upgrading of the logistics industry. High participation is also a matter of further research.

The theory of evolutionary game originated from the theory of biological evolution. It is the main analysis framework of individual or group limited rational behavior game. The research features of the two parties after continuous learning, attempts, and adjustment, and finally realizing the dynamic balance process characteristics. Different from the classic game, the evolution game is based on limited rationality and information asymmetry, effectively making up for the defects of complete rationality and complete information pile in the static game. The evolution game theory was initially applied to the analysis of biological populations. Small and medium -sized logistics companies choose digital transformation itself. It is also a strategic choice for enterprises to respond to market competition and survival. The game is applied to the strategy of digital transformation of small and medium -sized logistics companies. Based on this, this article attempts to use the evolutionary game method to explore the digital transformation decision -making mechanism of small and medium -sized logistics enterprises under the government -driven by government, in order to provide constructive opinions for the decision -making of enterprises and government departments.

2. Under the Market Mechanism, Small and Medium -Sized Logistics Companies Digital Transformation Game Model

2.1. Problem Description and Assumption

As the main body of the logistics industry in my country, small and medium -sized logistics companies are typical to choose to use small and medium -sized logistics companies as research objects. The small and medium -sized logistics enterprises are regarded as a system. In the state of "nature", the small and medium -sized logistics companies in the same area in the system are divided into group 1 and group 2. Select the strategic choice that is most conducive to the development of the enterprise. One enterprise is randomly selected in the group 1 and group 2 for the evolution game. It is marked as an enterprise 1. Enterprise 2. The strategy sets of the two are: digital transformation and no digital transformation. Make the following assumptions:

Hypothesis 1: The whole market contains N small markets that are identical and independent and located in different geographical locations, assuming that enterprise 1 and enterprise 2 are small and medium-sized logistics enterprises competing with each other in the market and the logistics products and services provided are homogeneous, and the consumers in the market where they are located are bounded rational, and are willing to choose more digital logistics products and services, and their demand is stable, which means that the different digital transformation strategies of enterprise 1 and enterprise 2 will affect the demand for their logistics products and services in the market.

Hypothesis 2: The probability of enterprise 1 undergoing digital transformation is $x(0 \le x \le 1)$ and the probability of choosing not to carry out digital transformation is $1-x$, the probability of enterprise 2 undergoing digital transformation is $y(0 \le y \le 1)$, and the probability of choosing not to carry out digital transformation is $1-y$, where x and y are both functions of time t.

Hypothesis 3: If the enterprise maintains the operation mode of the traditional logistics enterprise, the normal income when the digital transformation is not carried out is $P_i(i=1,2)$, if the enterprise chooses to carry out digital transformation, while paying the transformation cost $c_i(i=1,2)$, its logistics efficiency, enterprise management, resource utilization and other aspects will be improved due to the digital infrastructure, technology, management mode, etc., so that the direct income of the overall operation of the enterprise will increase $\alpha P_i(\alpha>0)$ compared with the original, where α is the direct income coefficient of the digital transformation of the enterprise.

Hypothesis 4: The total investment cost of digital transformation is $c_i(i=1,2)$, and the ability to provide logistics products and services is at least the same as that of the enterprise carrying out digital transformation. If small and medium-sized logistics enterprises 1 and 2 both choose to "carry out digital transformation", considering that digital transformation has positive externalities, enterprises can jointly participate in the construction of digital platforms or learn from each other's ideas or methods for transformation, so as to produce technological innovation synergy and complementary advantages, at this time, the cost investment of digital transformation is $C_i = c_i - \mu c_{3-i}(i=1,2)$, which also shows to a certain extent that the digital transformation of enterprises is not only related to their own strategies, but also related to the strategies of competitors, where μ is the synergy coefficient of transformation.

Hypothesis 5: In the era of digital economy, consumers in the market have a preference for digital logistics products and services, when one side of the enterprise chooses digital transformation, and the other side of the enterprise does not carry out digital transformation, its revenue changes to $\Delta P_i(i=1,2)$, that is, small and medium-sized logistics enterprises that choose to carry out digital transformation can reduce the overall logistics service cost through digitalization, and increase the output of q_i within a fixed time, their profits will increase ΔP_i, and the profits of small and medium-sized logistics enterprises that choose not to carry out digital transformation will reduce ΔP_i.

2.2. Game Analysis under Market Mechanism

According to the above assumptions, the payment matrix of small and medium-sized logistics enterprises 1 and 2 under the market mechanism is established, as shown in Table 1:

Table 1. Game payment matrix of small and medium-sized logistics enterprises under the market mechanism

		Enterprise 2	
		Embark on digital transformation	No digital transformation
Enterprise 1	Embark on digital transformation	$P_1+\alpha P_1-c_1+\mu c_2$ $P_2+\alpha P_2-c_2+\mu c_1$	$P_1+\alpha P_1+\Delta P_1-c_1$ $P_2-\Delta P_2$
	No digital transformation	$P_1-\Delta P_1$ $P_2+\alpha P_2+\Delta P_2-c_2$	P_1 P_2

As can be seen from Table 1, the returns U_{11}, U_{12} and the average expected returns $\overline{U_1}$ of enterprise 1 choosing the "conduct" and "no conduct" strategies are as follows:

$$U_{11} = y(P_1+\alpha P_1-c_1+\mu c_2)+(1-y)(P_1+\alpha P_1+\Delta P_1-c_1) \quad (1)$$

$$U_{12} = y(P_1-\Delta P_1)+(1-y)P_1 \quad (2)$$

$$\overline{U_1} = xU_{11}+(1-x)U_{12} \quad (3)$$

Similarly, the returns U_{21}, U_{22} and average expected returns $\overline{U_2}$ for Company 2 choosing the "Go" and "Don't" strategies are:

$$U_{21} = x(P_2+\alpha P_2-c_2+\mu c_1)+(1-x)(P_2+\alpha P_2+\Delta P_2-c_2) \quad (4)$$

$$U_{22} = x(P_2-\Delta P_2)+(1-x)P_2 \quad (5)$$

$$\overline{U_2} = yU_{21}+(1-y)U_{22} \quad (6)$$

The reproduction dynamic equations for enterprise 1 and enterprise 2 are as follows:

$$F(x,y) = x(U_{11}-\overline{U_1}) = x(1-x)(\mu c_2 y+\alpha P_1+\Delta P_1-c_1) \quad (7)$$

$$G(x,y) = y(U_{21}-\overline{U_2}) = y(1-y)(\mu c_1 x+\alpha P_2+\Delta P_2-c_2) \quad (8)$$

In order to analyze the evolution results of the game system, it is necessary to find the possible equilibrium point of the game, and further analyze whether it is an evolutionary stable strategy.

Let $F(x,y)=0$, $G(x,y)=0$ obtain: 5 local equilibrium points can be obtained on $R=\{(x,y)|0\le x,y\le 1\}$, which are $A_1(0,0)$, $A_2(0,1)$, $A_3(1,0)$, $A_4(1,1)$, $A_5(x^*,y^*)$. of which $x^*=-\dfrac{\alpha P_2+\Delta P_2-c_2}{\mu c_1}$, $y^*=-\dfrac{\alpha P_1+\Delta P_1-c_1}{\mu c_2}$.

In order to find the stable point of the system evolution, a Jacobian matrix is constructed, which is obtained by copying the partial derivatives of the dynamic equations $F_1(x,y)$ and $G_1(x,y)$ for x,y respectively [2], and the Jacobian matrix is as follow:

$$J=\begin{bmatrix}(1-2x)(\mu c_2 y+\alpha P_1+\Delta P_1-c_1) & x(1-x)\mu c_2\\ y(1-y)\mu c_1 & (1-2y)(\mu c_1 x+\alpha P_2+\Delta P_2-c_2)\end{bmatrix} \quad (9)$$

According to the replication dynamic equation, when $x=0,\ x=1$ or $y^*=-\frac{\alpha P_1+\Delta P_1-c_1}{\mu c_2}$, the strategy choice of enterprise 1's digital transformation can reach a relatively stable state, and when $y=0,\ y=1$ or $x^*=-\frac{\alpha P_2+\Delta P_2-c_2}{\mu c_1}$, the strategy choice of enterprise 1's digital transformation can reach a relatively stable state, and the strategy choice of enterprise 2's digital transformation tends to be stable. In the $R=\{(x,y)|0\le x,y\le 1\}$ plane, according to $0\le -\frac{\alpha P_2+\Delta P_2-c_2}{\mu c_1}\le 1, 0\le -\frac{\alpha P_1+\Delta P_1-c_1}{\mu c_2}\le 1$, $0\le -(\alpha P_2+\Delta P_2-c_2)\le \mu c_1, 0\le -(\alpha P_1+\Delta P_1-c_1)\le \mu c_2$ can be obtained, and the results are shown in Table 2 for the analysis of each equilibrium point under the above constraints:

Table 2. Analysis results of local stability of digital transformation of small and medium-sized logistics enterprises under market mechanism

Equilibrium point	Determinant symbols	Traces of symbols	stability
$A_1(0,0)$	+	-	*ESS*
$A_2(0,1)$	+	+	Unstable points
$A_3(1,0)$	+	+	Unstable points
$A_4(1,1)$	+	-	*ESS*
$A_5(x^*,y^*)$	-	0	Unstable points

As can be seen from Table 2, the player will reach two different stability points: $A_1(0,0)$ and $A_4(1,1)$. First of all, the representative's strategy is to carry out digital transformation or not to carry out digital transformation, and the path chosen by the digital transformation strategy of both parties is shown in Figure 1.

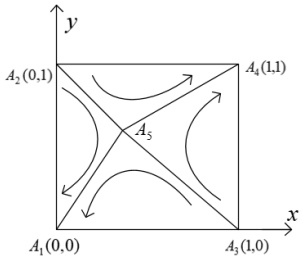


Figure 1. Evolutionary phase diagram of the two sides of the game under the market mechanism

As can be seen from Figure 1, the evolution of A_1 and A_4 is characterized by two stable outcomes. A_2 and A_3 belong to the unstable points, and they and A_5 points demarcate the strategic boundaries of both sides of the game. From the perspective of outcome evolution, both sides of the game will evolve towards point A_1 (neither digital transformation) or A_4 (both digital transformation). If the choice strategy of both players is located in 7777, the result will evolve in the direction of $A_1A_2A_5A_3$ points, and will eventually converge to A_1, and both sides of the game choose the strategy of "no digital transformation". If the game strategy of the two is located in $A_2A_5A_3A_4$, then the result will continue to evolve towards A_4 and will eventually converge to A_4, at which time both sides choose the strategy of "digital transformation". If $S_{A_1A_2A_5A_3}$ is S_1, then the area of $A_1A_2A_5A_3$ can be expressed as:

$$S_{A_1A_2A_5A_3}=S_1=\frac{1}{2}(x^*+y^*)=-\frac{1}{2}\left(\frac{\alpha P_2+\Delta P_2-c_2}{\mu c_1}+\frac{\alpha P_1+\Delta P_1-c_1}{\mu c_2}\right)$$

From the formula of S_1, it can be seen that the parameters that affect the area size of S_1 are P_i、ΔP_i、c_i、α、μ, and the partial derivatives of these parameters are obtained respectively, and "+" indicates that the parameters are positively correlated with S_1, "-" indicates that the parameters are negatively correlated with S_1, and "/" indicates that the correlation between the parameters and S_1 cannot be distinguished, and the results are shown in Table 3:

Table 3. Analysis of the Influence of Parameters on the Choice of Cooperative Strategies of Game Participants

Parameters,	Partial derivatives	Effects on S_1
P_i	-	-
ΔP_i	-	-
c_i	+	+
α	-	-
μ	-	-

It can be seen from Table 3 that the willingness of small and medium-sized logistics enterprises to digitally transform is positively correlated with $P_i, \Delta P_i, \alpha, \mu$ and negatively correlated with c_i, that is, the willingness of small and medium-sized logistics enterprises to carry out digital transformation becomes stronger with the increase of the direct benefit coefficient and synergy coefficient of transformation and the income generated by consumers' preference for digital services, that is, the essence of enterprises is to seek profit maximization. When the input cost of transformation is too high, enterprises will measure the input-output ratio of transformation, and if the transformation faces large input costs, it will reduce the willingness of small and medium-sized logistics enterprises to digitally transform. Therefore, for the government, in order to promote the modernization of China's logistics industry and improve the willingness of small and medium-sized logistics enterprises to digitally transform, the government can effectively make up for the cost of enterprises through relevant incentive policies, reduce the cost of transformation of enterprises and build a digital transformation platform, so as to enhance the willingness of small and medium-sized logistics enterprises to digitally transform.

3. The Digital Transformation Game Model of Small and Medium-Sized Logistics Enterprises Driven by the Government

3.1. Problem Description and Assumption

From the above analysis, it can be seen that the digitalization of small and medium-sized logistics enterprises in China is affected by factors such as enterprise input cost, synergy coefficient and direct benefit coefficient, and when the transformation input cost is too high, it may lead to low willingness of small and medium-sized logistics enterprises to transform. In order to promote the modernization of China's logistics industry, it is necessary for the government to take macro-control measures to encourage and guide small and medium-sized logistics enterprises to carry out digital transformation.

At present, China's incentives for small and medium-sized enterprises mainly include providing relevant subsidies, talent introduction, platform construction and other incentives for small and medium-sized logistics enterprises. From the perspective of government subsidies for industrial transformation, there are two main types, one is the subsidy implemented for the cost input, production, sales and other operation processes of enterprise products, that is, direct subsidies for logistics products and services [3], such as subsidies for logistics and transportation costs and service quantities. The other category is innovative subsidies represented by industrial transformation and upgrading guidance funds, technological transformation, and enterprise innovation [4].

Based on the above description, the following assumptions are added to the previous assumptions:

Hypothesis 6: In order to promote the digital transformation of small and medium-sized logistics enterprises in China and improve their digital technology capabilities, the government will carry out relevant support policies and directly provide financial subsidies to small and medium-sized logistics enterprises that carry out digital transformation, and set the government's subsidy amount for transformation enterprises as m.

Hypothesis 7: In addition to the direct financial subsidies from the government for digital transformation, if small and medium-sized logistics enterprises can provide differentiated digital logistics services for market consumers through digital transformation, they will gain more market share, in order to further enhance the willingness of enterprises to transform, the government will also provide additional tax incentives for logistics services that increase due to transformation, and set the tax incentives for n, then the tax incentives that enterprises that carry out digital transformation can get are nq_i

3.2. Government-driven Game Analysis

According to the above assumptions, the payment matrix of small and medium-sized logistics enterprises 1 and 2 under the government's drive is established, as shown in Table 4.

Table 4. The game payment matrix of small and medium-sized logistics enterprises driven by the government

		Enterprise 2	
		Embark on digital transformation	No digital transformation
Enterprise 1	Embark on digital transformation	$P_1+\alpha P_1-c_1+\mu c_2+m,$ $P_2+\alpha P_2-c_2+\mu c_1+m$	$P_1+\alpha P_1+\Delta P_1+nq_1$ $-c_1+m,$ $P_2-\Delta P_2$
	No digital transformation	$P_1-\Delta P_1,$ $P_2+\alpha P_2+\Delta P_2+nq_2-c_2+m$	P_1, P_2

As can be seen from Table 1, the V_{11}, V_{12} and average expected $\overline{V_1}$ of enterprise 1 choosing the "conduct" and "do not" strategies are as follows:

$$V_{11}=y(P_1+\alpha P_1-c_1+\mu c_2+m)+(1-y)(P_1+\alpha P_1+\Delta P_1+nq_1-c_1+m) \tag{10}$$

$$V_{12}=y(P_1-\Delta P_1)+(1-y)P_1 \tag{11}$$

$$\overline{V_1}=xV_{11}+(1-x)V_{12} \tag{12}$$

As can be seen from Table 1, the V_{21}, V_{22} and average expected $\overline{V_2}$ of enterprise 1 choosing the "conduct" and "do not" strategies are as follows:

$$V_{11}=x(P_2+\alpha P_2-c_2+\mu c_1+m)+(1-x)(P_2+\alpha P_2+\Delta P_2+nq_2-c_2+m) \tag{13}$$

$$V_{22}=x(P_2-\Delta P_2)+(1-x)P_2 \tag{14}$$

$$\overline{V_2}=yV_{21}+(1-y)V_{22} \tag{15}$$

The reproduction dynamic equations for enterprise 1 and enterprise 2 are as follows:

$$f(x,y)=x(V_{11}-\overline{V_1})=x(1-x)[(\mu c_2-nq_1)y+\alpha P_1+\Delta P_1+nq_1-c_1+m] \tag{16}$$

$$g(x,y)=y(V_{21}-\overline{V_2})=y(1-y)[(\mu c_1-nq_2)x+\alpha P_2+\Delta P_2+nq_2-c_2+m] \tag{17}$$

In order to obtain the equilibrium point of small and medium-sized logistics enterprises in the game, assuming $F(x,y)=0,\ G(x,y)=0$, five local equilibrium points $R=\{(x,y)|0\le x,y\le 1\}$ can be obtained on $B_1(0,0),\ B_2(0,1),\ B_3(1,0),\ B_4(1,1),\ B_5(x^*,y^*)$, wherein: $x^*=-\frac{\alpha P_2+\Delta P_2+nq_2-c_2+m}{\mu c_1-nq_2}, y^*=-\frac{\alpha P_1+\Delta P_1+nq_1-c_1+m}{\mu c_2-nq_1}$

Jacobian matrices for building game systems:

$$J=\begin{bmatrix}\frac{\partial f}{\partial x} & \frac{\partial f}{\partial y}\\ \frac{\partial g}{\partial x} & \frac{\partial g}{\partial y}\end{bmatrix} \tag{18}$$

In order to obtain the replication dynamic equation of small and medium-sized logistics enterprises, the strategy of digital

transformation adopted by enterprise 1 is stable when $x=0, x=1, y^*=-\frac{\alpha P_1+\Delta P_1+nq_1-c_1+m}{\mu c_2-nq_1}$ is obtained, and the strategy of digital transformation adopted by enterprise 2 is stable when $y=0, y=1, x^*=-\frac{\alpha P_2+\Delta P_2+nq_2-c_2+m}{\mu c_1-nq_2}$ is obtained. Within the $R=\{(x,y)|0\le x,y\le 1\}$ plane, the constraints can be obtained according to the $0\le x^*, y^*\le 1$: $0\le -(\alpha P_2+\Delta P_2+nq_2-c_2+m)\le \mu c_1-nq_2$ and $0\le -(\alpha P_1+\Delta P_1+nq_1-c_1+m)\le \mu c_2-nq_1$. Under the above constraints, the stability analysis results of each equilibrium point are shown in Table 5:

Table 5. Analysis results of local stability of digital transformation of small and medium-sized logistics enterprises under market mechanism

Equilibrium point	Determinant symbols	Traces of symbols	stability
$B_1(0,0)$	+	-	*ESS*
$B_2(0,1)$	+	+	Unstable points
$B_3(1,0)$	+	+	Unstable points
$B_4(1,1)$	+	-	*ESS*
$B_5(x^*,y^*)$	-	0	Unstable points

As can be seen from Table 5, the stability point, instability point, and saddle point of the government-driven game system are the same as those under the market mechanism, so the evolutionary phase diagram is the same as that in Figure 1. The instability of the game system will eventually move towards the B_1 and B_4 points, but it still depends on the $B_2B_5B_3B_4$ and $B_1B_2B_5B_3$. If $S_{B_1B_2B_5B_3}$ is S_2, there are:

$$S_2=-\frac{1}{2}\left(\frac{\alpha P_1+\Delta P_1+nq_1-c_1+m}{\mu c_2-nq_1}+\frac{\alpha P_2+\Delta P_2+nq_2-c_2+m}{\mu c_1-nq_2}\right)$$

Since the main purpose of the model is to discuss the influence mechanism of government subsidies on the digital transformation strategy of small and medium-sized logistics enterprises, the derivatives of m,n are obtained separately, and the influence of the parameter m,n on S_2 is discussed.

Deriving m yields:

$$\frac{\partial S_2}{\partial m}=-\frac{1}{2}\left(\frac{1}{\mu c_2-nq_1}+\frac{1}{\mu c_1-nq_2}\right)<0$$

It can be seen that there is a negative correlation between m and S_2, that is, when m increases, S_2 will gradually decrease, and the overall result will be biased towards $B_4(1,1)$, indicating that the probability of digital transformation of small and medium-sized logistics enterprises increases with the increase of direct subsidies from the government.

Deriving n shows that:

$$\frac{\partial S_2}{\partial n}=-\frac{1}{2}\left[\frac{(\alpha P_1+\Delta P_1-c_1+\mu c_2+m)q_1}{(\mu c_2-nq_1)^2}+\frac{(\alpha P_2+\Delta P_2-c_2+\mu c_1+m)q_2}{(\mu c_1-nq_2)^2}\right]<0$$

Similarly, it can be seen that there is a negative correlation between n and S_2, that is, when n increases, S_2 will gradually decrease, and the overall result will be biased towards $B_4(1,1)$, indicating that the probability of digital transformation of small and medium-sized logistics enterprises increases with the increase of the government's tax incentives for incremental logistics products and services due to digital transformation.

4. Numerical Simulation

4.1. Numerical Simulation

In order to further illustrate the influence mechanism of direct profit, cost and government on transformation decision-making, Matlab R2018a was selected to perform numerical simulation analysis of some parameters (the dimension does not affect the conclusion of the paper). In order to ensure the reliability and generalizability of the research structure in this paper, and the scientificity and rationality of the setting parameters, the simulation parameters of this paper are set as follows by combining the setting law methods of Meng Fansheng et al. [5], Zhang Zhengang et al. [6], Xu Jianzhong [7] and others:

Table 6. The initial value of each parameter

Parameters	P_1	P_2	ΔP_1	ΔP_2	c_1	c_2	q_1	q_2	μ	α	m	n
Assignments	5.4	4.2	3	2.6	11	9	0.6	0.6	0.5	1	0.5	0.5

4.2. Simulation Analysis under Market Mechanism

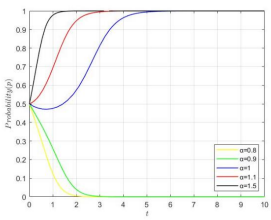


Figure 2(a). Effect of the direct profit factor on firm 1

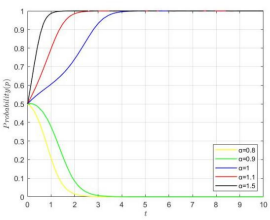


Figure 2(b). Effect of the direct profit factor on firm 1

1. The impact of the direct revenue coefficient on the digital transformation of small and medium-sized logistics enterprises

With all other parameters unchanged and the initial probability of 0.5, the evolution path of both sides of the game when $\alpha=0.8,0.9,1,1.1,1.5$ is given, as shown in Figure 2.

As can be seen from Figure 2, when $\alpha=0.8,0.9$, the evolution direction tends to be 0 probability (no digital transformation is carried out), indicating that when the direct profit obtained from transformation is too low, enterprises are not willing to carry out digital transformation, and they are more willing to maintain the status quo. However, when $\alpha=1,1.1,1.2$, especially when $\alpha=1,1.1,1.2$, the probability curve of small and medium-sized logistics enterprises to implement digital transformation quickly becomes very steep, and converges at a very fast speed to probability 1 (all of which are engaged in digital transformation). This is because logistics companies have significantly improved their profits through the deep integration with digital technology, which

has greatly increased the enthusiasm for digital transformation among enterprises. Therefore, the higher the profit that a company can gain from transformation, the higher the willingness of the enterprise to digitally transform.

2. The impact of the digital transformation of small and medium-sized logistics enterprises with synergy coefficient

With all other parameters unchanged and the initial probability of $x=0.5, y=0.5$, the evolution path of both sides of the game when $\mu=0.3,0.4,0.5,0.6$ is maintained, as shown in Figure 3:

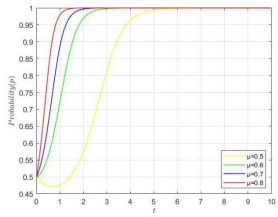


Figure 3(a). The impact of the synergy coefficient on firm 1

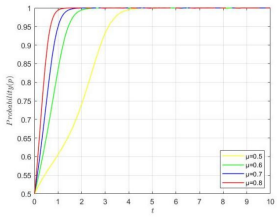


Figure 3(b). The impact of the synergy coefficient on firm 2

It can be seen from Figure 3 that in $\mu=0.5$, compared with enterprise 2, the oblique trajectory of enterprise 1 first changes from large to small, and then from small to large, because when the parameters are set, the initial profit of enterprise 1 itself is higher than that of enterprise 2, so enterprise 1 belongs to the party with stronger initial endowment in the regional market, so its willingness to carry out collaborative transformation with enterprise 2 is not so strong. When the μ exceeds a certain threshold, such as $\mu=0.6,0.7,0.8$, both parties quickly evolve towards probability 1 (both carry out digital transformation), which indicates that a reasonable spillover coefficient can greatly reduce the cost of transformation for both parties, thereby driving both enterprises to jointly carry out digital transformation. Overall, μ has a positive incentive effect on the digital transformation of small and medium-sized logistics enterprises.

4.3. Simulation Analysis with Government Encouragement

1. The impact of direct government subsidies on the digital transformation of small and medium-sized logistics enterprises

The government has invested a certain amount of financial subsidies for the innovative behavior of digital transformation of small and medium-sized logistics enterprises, which can improve the digital transformation process of enterprises faster. The impact of direct government subsidies on small and medium-sized logistics enterprises is shown in Figure 4:

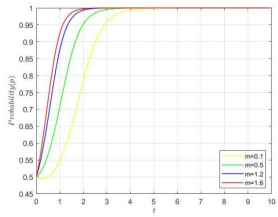


Figure 4(a). The impact of direct government subsidies on enterprises1

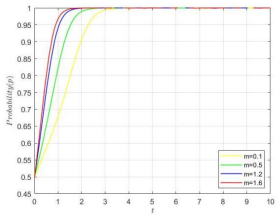


Figure 4(b). The impact of direct government subsidies on enterprises2

As can be seen from Figure 4, if the value of direct subsidy is $m=0.5$, then the evolution speed of digital transformation of small and medium-sized logistics enterprises is faster than that of $m=0.1$. In the case of $m=1.2$, the evolution rate is faster than that of $m=0.1,0.5$, but the magnitude of the change is not as large as that of SSSS. Therefore, the government's direct subsidy has a positive incentive effect on the digital transformation of enterprises, and the larger the value, the more obvious the effect, but the increase of the government's direct subsidy beyond a certain range has no obvious effect on the evolution of the system to a stable point (all digital transformation). Therefore, in the face of different market conditions, the government should consider the amount of direct subsidies in combination with various factors, so as to better encourage small and medium-sized logistics enterprises to carry out digital transformation. If the government invests a large amount of financial subsidies for the transformation of enterprises, then the marginal effect of incentive policies will be smaller while the government bears the financial pressure, which will hinder the digital transformation of small and medium-sized logistics enterprises.

2. The impact of tax incentives on the digital transformation of small and medium-sized logistics enterprises

In addition to directly providing financial subsidies to small and medium-sized logistics enterprises that carry out digital transformation, the government also provides tax incentives for the incremental logistics products and services generated by the transformation. The impact of tax incentives on the digital transformation of small and medium-sized logistics enterprises is shown in Figure 5.

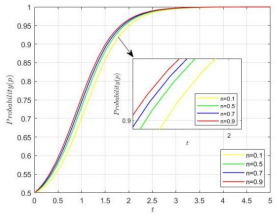


Figure 5(a). The impact of tax incentives on enterprises1

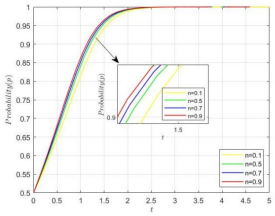


Figure 5(b). The impact of tax incentives on enterprises1

As can be seen from Figure 5, when the n tax incentives are equal to different values, there are differences in the evolution direction of digital transformation decisions of small and medium-sized logistics enterprises when other parameters are stable. In the case of $x=0.5, y=0.5$, the government's tax incentives can encourage small and medium-sized logistics enterprises to choose the decision to carry out digital transformation, and with the enhancement of incentives, the willingness is stronger, and both parties are more inclined to choose digital transformation.

3. The impact of direct government subsidies and tax incentives on the digital transformation of small and medium-sized logistics enterprises under different subsidy levels

As can be seen from Figure 6, the government's support is too low $(m=0.1, n=0.1)$, medium $(m=0.5, n=0.5)$, and high $(m=0.9, n=0.9)$, which will increase the willingness of small and medium-sized logistics enterprises 1 and 2 to digitally transform. By comparing the curves in the graph, it can be seen that if the direct subsidies and tax incentives are strong, the evolution of the system to probability 1 will also be accelerated. When the direct subsidy is too low and the tax preference is high, the evolution speed of the system to (1,1)

is faster than that when the direct subsidy is high and the tax incentive subsidy is low. Therefore, small and medium-sized logistics enterprises are more sensitive to direct subsidies given by the government, that is, the subsidy effect of direct subsidies is more obvious than that of tax incentives.

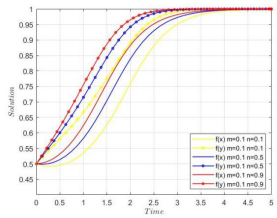


Figure 6(a). The impact of different government subsidies and tax incentives on the system

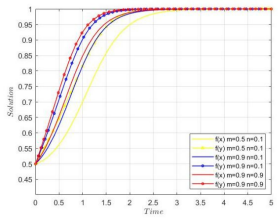


Figure 6(b). The impact of different government subsidies and tax incentives on the system

5. Conclusion and Implications

Considering the problems existing in the digital transformation of small and medium-sized logistics enterprises, this paper uses the ideas and methods of evolutionary game to construct a dynamic evolution model of small and medium-sized logistics enterprises in choosing digital transformation strategies driven by the market and the government, analyzes the stability of the evolutionary strategy combination and the influence of key variables on the strategy evolution and stability results, and tests the effectiveness of the analysis process and conclusions in combination with simulation, and draws the following conclusions: direct benefit coefficient, The degree of consumers' digital preference for products and services can significantly enhance the willingness of small and medium-sized logistics enterprises to digitally transform, that is, the direct benefits brought by the deep integration of digital technology and logistics operations to small and medium-sized logistics enterprises, as well as the benefits generated by satisfying the digital preferences of market consumers through digital logistics products and services, are the key factors for them to consider whether to carry out digital transformation, and the increase in the input cost of digital transformation will reduce the willingness of small and medium-sized logistics enterprises to implement digital transformation. In addition, the transformation of small and medium-sized logistics enterprises can improve the synergy coefficient by learning from each other and participating in the construction of digital platforms, thereby reducing each other's transformation costs. Therefore, the government can start from the perspective of reducing the cost of transformation of small and medium-sized logistics enterprises, and enhance the willingness of small and medium-sized logistics enterprises to digitally transform through a series of incentives. Through the simulation of government direct subsidies and preferential tax subsidies under different intensities, the effect of direct subsidies is better, which is more conducive to enhancing the willingness of small and medium-sized logistics enterprises to digitally transform and help the transformation and upgrading of China's logistics industry.

Based on the above conclusions, the following enlightenment can be drawn: (1) small and medium-sized logistics enterprises can optimize the digital service experience of their products and learn from each other with enterprises in the same industry or jointly participate in the construction of digital platforms, which can improve consumers' preference for digital products on the one hand, thereby increasing the benefits they can obtain from transformation, and on the other hand, they can reduce the input cost of their transformation through technological collaboration; (2) The government should actively play its role in encouraging the digital transformation of small and medium-sized logistics enterprises. Considering that government subsidies have a positive incentive effect on the digital transformation of small and medium-sized logistics enterprises, the government can set up special funds for digital transformation to support the digital transformation of small and medium-sized logistics enterprises; In addition, considering the difference in the effect of different subsidy levels, the government can formulate more reasonable subsidy methods according to different markets; (3) In order to enhance the willingness of small and medium-sized logistics enterprises to jointly transform, the information resources of the government and small and medium-sized logistics enterprises can be used to jointly build a digital transformation platform and promote the collaborative digital transformation of small and medium-sized logistics enterprises.

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